Static Stretching Can Impair Explosive Performance for At Least 24 Hours

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Abstract

Haddad, M, Dridi, A, Chtara, M, Chaouachi, A, Wong, DP, Behm, D, and Chamari, K. Static stretching can impair explosive performance for at least 24 hours. *J Strength Cond Res* 28(1): 140–146, 2014—The aim of this study was to compare the effects of static vs. dynamic stretching (DS) on explosive performances and repeated sprint ability (RSA) after a 24-hour delay. Sixteen young male soccer players performed 15 minutes of static stretching (SS), DS, or a no-stretch control condition (CC) 24 hours before performing explosive performances and RSA tests. This was a within-subject repeated measures study with SS, DS, and CC being counterbalanced. Stretching protocols included 2 sets of 7 minutes 30 seconds (2 repetitions of 30 seconds with a 15-second passive recovery) for 5 muscle groups (quadriceps, hamstring, calves, adductors, and hip flexors). Twenty-four hours later (without any kind of stretching in warm-up), the players were tested for the 30-m sprint test (with 10- and 20-m lap times), 5 jump test (5JT), and RSA test. Significant differences were observed between CC, SS, and DS with 5JT ($F = 9.99$, $p < 0.00$, effect size [ES] = 0.40), 10-m sprint time ($F = 46.52$, $p < 0.00$, ES = 0.76), 20-m sprint time ($F = 18.44$, $p < 0.000$, ES = 0.55), and 30-m sprint time ($F = 34.25$, $p < 0.000$, ES = 0.70). The significantly better performance ($p < 0.05$) was observed after DS as compared with that after CC and SS in 5JT, and sprint times for 10, 20, and 30 m. In contrast, significantly worse performance ($p < 0.05$) was observed after SS as compared with that after CC in 5JT, and sprint times for 10, 20, and 30 m. With RSA, no significant difference was observed between different stretching protocols in the total time ($F = 1.55$, $p > 0.05$), average time ($F = 1.53$, $p > 0.05$), and fastest time ($F = 2.30$, $p > 0.05$), except for the decline index ($F = 3.54$, $p < 0.04$, ES = 0.19). Therefore, the SS of the lower limbs and hip muscles had a negative effect on explosive performances up to 24 hours poststretching with no major effects on the RSA. Conversely, the DS of the same muscle groups are highly recommended 24 hours before performing sprint and long-jump performances. In conclusion, the positive effects of DS on explosive performances seem to persist for 24 hours.

Key Words soccer, stretching protocols, jump, repeated sprint

Introduction

Static stretching (SS) was considered an essential component of a warm-up for decades (39) to improve performance. Traditionally, after a submaximal aerobic component (i.e., running, cycling), the second component was a bout of SS (39). The SS usually involves moving a joint to the end of its range of motion (ROM) and holding the stretched position for 15–60 seconds (39). The SS has been demonstrated as an effective means to increase ROM (26). This bout of stretching is commonly followed by a segment of skill rehearsal where the players would perform dynamic movements similar to the sport or event for which they were preparing (39). A review by Behm and Chaouachi (2) summarized the plethora of studies reporting that SS can lead to impairments in subsequent performance. However, they highlighted the greater variability in the findings with shorter durations of stretching (<90 seconds per muscle group). In addition, SS does not lead to such pervasive negative effects with sprinting and running activities (13,34).

Recently, many studies have shown that a moderate duration of stretching (15–30 seconds of SS per muscle group) does not affect short-term muscle strength (8,24). In contrast, studies implementing 30 (36), 60 (34), or 90 seconds (29) resulted in decreased jump height. In the same context, other studies have shown that SS before a competition is harmful for strength, speed, and jumping performances (5). Presently, the overwhelming consensus is against SS before subsequent performance, especially involving higher velocities and power.

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Brandenburg et al. (3) examined the effects of SS on countermovement vertical jump (CMVJ) ability. They found that CMVJ height decreased immediately post-SS in comparison with CMVJ pre-SS, and it remained decreased during the 24 minutes follow-up period. Power et al. (26) demonstrated that these deficits occur 1 minute post-SS and continue until 120 minutes poststretching. This study did not show impairments in jump height performance; however, the quadriceps force remained decreased, and jump contact time was increased for 120 minutes. Therefore, SS can have negative effects on muscular force up to 2 hours.

Dynamic stretching (DS), which involves controlled movement through the active ROM for each joint (9), is currently replacing SS in the modern athletic warm-up. However, it is important to not ignore the SS studies that report no impairments as they may reveal stretch-related mechanisms and opportunities to employ SS before performance (2). The DS has been shown to enhance performance in subsequent dynamic concentric external resistance (38), explosive (22,38), agility (22), sprint performance (10), vertical jump height (9,17), and increased electromyographic activity during an isometric maximal voluntary contraction (MVC) (14). A few studies have demonstrated no adverse effect rather than potentiation with DS (6,31). The DS may also enhance muscular performance because of postactivation potentiation, which is the transient improvement of muscular performance after previous contraction (6,31). In this context, Turki et al. (33) showed that 10 minutes of DS of the lower limbs had a substantial likelihood of augmenting vertical jump (VJ) height, peak power, velocity, and force. Hough et al. (17) instituted 7 minutes of DS resulting in an increased vertical jump height. However, all the aforementioned studies were interested in the short-term effect of stretching on performance (from immediate effect to 120 minutes [20] postintervention). There are no studies investigating the effect of stretching 24 hours later. Therefore, the purpose of this study was to investigate the effects of 2 different types of stretching (SS and DS) and control condition (CC) on sprint tests, 5 jump test (5JT), and repeated sprint ability (RSA) after 24 hours. It was hypothesized that the positive effects of DS on explosive performances, running speed, and RSA would persist for at least 24 hours.

Methods

Experimental Approach to the Problem

To examine the effect of 2 types of stretching 24 hours before performing the sprint, 5JT, and RSA tests, all the players performed the 3 experimental conditions (SS, DS, and CC) in a counterbalanced order in this within-subject repeated measures study. The study lasted for 4 weeks where the first week was used for familiarization of the tests and anthropometric measurements, and the actual tests were performed at the end of the second–fourth weeks (Sunday). The players' running speed (30-m sprint with 10-m lap time), lower-body explosive power (5JT), and RSA were assessed.

Subjects

Sixteen volunteer junior players (between 17 and 19 years old) were recruited among professional soccer team competing in First league. All the players were not injured at least 4 weeks before the beginning of the study. The characteristics of players are presented in Table 1. Players' typical training regimen included 7 training sessions for 6 $d \cdot wk^{-1}$, 90–120 minutes in duration. All the participants gained medical clearance from the team physician to ensure that they were in good health. Before the study, all the players and parents were informed about the potential risks and benefits associated to participation, and both signed a written informed consent form, agreeing with the protocol procedures and publication of the data. The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the Clinical Research Ethics Committee of the National Center of Medicine and Science in Sports of Tunis, Tunisia before the beginning of the assessments. All the players were fully accustomed to the procedures used in this research and were informed that they could withdraw from the study in any time without penalty.

Procedures

Data were collected during 4 weeks of the precompetitive season without friendly matches. All the sessions were performed in the soccer stadium at the same hour of the day starting at 15:00 hours in average ambient conditions of 13.0 ± 1.7° C temperature, 1,016.4 ± 3.9 mmHg atmospheric pressure, and 69.8 ± 0.1% relative humidity. In the first week, all the players attended 3 orientation sessions (once a day). The morning of the first day was delegated to anthropometric measurements. The afternoon of the second and third days, familiarization sessions for all the stretching and testing protocols were organized. A standardized warm-up (e.g., general physical preparation with joint and muscular mobilization) was performed before each training session during the first week. During the second to fourth weeks, the players performed 1 of the 3 stretching protocols in a counterbalanced order,

Table 1. Characteristics of players.

Age (y)	Height (m)	Body mass (kg)	%Body fat	MAS* ($km \cdot h^{-1}$)	$\dot{V}O_2max$ ($ml \cdot min^{-1} \cdot kg^{-1}$)
18.2 ± 1.2	1.77 ± 5.80	70.65 ± 7.80	11.32 ± 2.30	16.01 ± 1.90	53.2 ± 3.6

*MAS = maximal aerobic speed.

24 hours before the performance tests. In this study, we selected test items that have been reported to have high discriminating power among young soccer players and related to match performance. In this context, Reilly et al. (28) compared elite and subelite young soccer players and found that sprint time was the most discriminating measure. Specifically, 30-m sprint (with 10-m lap time) has been suggested as a standard sprint test for soccer players. In addition, 5JT was used to estimate athlete's lower limb explosive power (4). It has been reported to be correlated with the 5-, 10-, and 30-m sprint performance and with vertical jump performance in soccer players (4). To measure the ability to repeat sprints in soccer, RSA tests were designed. The RSA tests used in this study was significantly correlated with both high-speed running and sprinting distance during actual match play (27). Details of these tests were described below. There was no stretching in warm-up immediately before the tests. The various tests were administered by the same experimenter in the same condition for all players. For diet monitoring, each player was given a meal plan (food and hydration) composed in collaboration with the club's nutritionist. During the period of investigation, they were prohibited from consuming any known stimulant (e.g., caffeine) or depressants (e.g., alcohol) substance. To avoid dehydration, ad libitum drinking was permitted during all the training sessions.

Stretching Protocols. Two stretching protocols were performed: SS and DS. These stretching protocols have been used in various studies (9,32). The SS and DS consisted of 2 sets of 7 minutes 30 seconds each for 5 muscle groups (i.e., quadriceps, hamstrings, plantar flexors, adductors, and hip flexors). Two sets of stretching per muscle group were performed (30 seconds for the right and 30 seconds for the contralateral left muscle group) with a 15-second recovery between repetitions and a 3-minute recovery between sets. Static and dynamic protocols stretched the same muscular groups.

Field Testing

Five Jump Test. This test (4) was performed on the grass with the players equipped with appropriate soccer boots. The 5JT consists of 5 consecutive strides with feet together at the start and end of the jumps. From the starting position, the participant was not allowed to perform a back step with any foot; rather, he had to directly jump to the front with a leg of his choice. After the first 4 strides, that is, alternating left and right feet 2 times each, he had to perform the last stride and end the test again with feet together. If the player fell back on completion of the last stride, the test was performed again (only 2 instances in this study). Five jump-test performances were measured with a tape measure from the front edge of the player's feet at the starting position to the rear edge of the feet at the final position (4). The person assessing the landing had to focus on the last stride of the player to exactly determine the last footprint on the grass, as the players could not always stay on their feet on landing. The starting position was set on a fixed point (4).

Thirty-Meter Sprint. The players had to start from a standing position placing their forward foot just behind the starting line. They performed a 30-m sprint with a stationary start and the timing started when the subjects crossed the starting line (beam of the first photocell gate located at 0 m). The speed was measured with an infrared photoelectronic cell (Speedtrap II Wireless Timing System; Brower Timing System, Draper, UT, USA) positioned at 10, 20, and 30 m from the starting line at a height of 50 cm. There were 3 trials in total, and a 3-minute recovery was allowed between each trial. The best (fastest) 30-m sprinting time and the associated 10- and 20-m sprinting time were selected for analysis.

Repeated Sprint Ability Test. This test was designed to measure both repeated sprint and change in direction abilities (27). The athletes started from a line, sprinted for 20 m, touched a line with a foot, and came back to the starting line as fast as possible. After 20 seconds of passive recovery, the subject started again (27). Immediately after the warm-up, each player completed a preliminary single shuttle sprint test using a photocells system (Speedtrap II Wireless Timing System; Brower Timing System). This trial was used as the criterion score during the subsequent 6×40-m shuttle sprint test. After the first preliminary single shuttle sprint, the subjects rested for 5 minutes before the start of the RSA test. If the performance in the first sprint of the RSA test was worse than the criterion score (i.e., an increase in time $>2.5\%$), the test was terminated immediately, and the subjects were required to repeat the RSA test with maximum effort after a 5-minute rest. Five seconds before the start of each sprint, the subjects assumed the ready position and waited for the start signal (27). During the RSA test, total, average and fastest times and the index of decline (%dec) were calculated.

Statistical Analyses

Mean $\pm$ *SD* was used to describe variables. Before using parametric tests, the assumption of normality was verified using the Kolmogorov-Smirnov test. A 1-way analysis of variance (ANOVA) for repeated measures was used to examine the difference between conditions (CC, SS, and DS), respectively, in 5JT, sprints, and RSA. When significant F values were observed ($p \leq 0.05$), paired comparisons were used in conjunction with Holm's Bonferroni method for controlling type 1 error (15) to determine significant differences. The effect size (ES) was calculated for all ANOVAs with the use of a partial eta-squared. Values of 0.01, 0.06, and >0.15 were considered as small, medium, and large, respectively (7). The ESs were also calculated for all paired comparisons and evaluated with the method described by Cohen (7) (small <0.50, moderate $=$ 0.50–0.79, and large >0.80). Reliability of each test was assessed before the start of this study by intraclass correlation coefficient (ICC) and the *SEM*. Statistical analyses were performed using SPSS software statistical package (version 16.0; SPSS Inc., Chicago, IL, USA), and statistical significance was set at $p \leq 0.05$.

Table 2. Physical performances 24 hours after different stretching protocols ($n = 16$).*

		No stretching control	Static stretching	Dynamic stretching	ANOVA p	Effect size†	Statistical power
5 JT (m)		12.33 (0.52)‡	12.23 (0.58)‡	12.53 (0.51)§	0.00	0.40	0.98
Sprint (s)	10 m	1.77 (0.13)‡§	1.82 (0.15)‡	1.73 (0.13)§	0.00	0.76	1.0
	20 m	3.21 (0.14)‡§	3.26 (0.14)‡	3.17 (0.14)§	0.00	0.55	1.0
	30 m	4.32 (0.23)‡§	4.36 (0.23)‡	4.27 (0.23)§	0.00	0.70	1.0
RSA (s)	Total time	46.00 (0.82)	45.93 (0.80)	46.10 (1.00)	0.23	0.09	0.30
	Mean time	7.67 (0.14)	7.66 (0.13)	7.68 (0.17)	0.23	0.09	0.30
	Best time	7.38 (0.14)	7.39 (0.13)	7.37 (0.14)	0.12	0.13	0.43
	% Decrement	3.88 (1.37)	3.63 (1.45)	4.28 (1.86)	0.04	0.19	0.61

*ANOVA = analysis of variance; 5JT = 5 jump-test; RSA = repeated sprint ability.
†Effect size of the ANOVA comparison, that is, the comparison between 3 groups at the same time.
‡Significantly different from static stretching at $p < 0.05$.
§Significantly different from dynamic stretching at $p < 0.05$.

Results

Statistical Power and Reliability

The statistical power of this study ranged from 0.30 to 1.0 (Table 2). In addition, the results show that the tests were highly reliable: 30-m sprint (ICC = 0.81; *SEM* = 1.89; $n = 16$), 5JT (ICC = 0.95; *SEM* = 0.08; $n = 16$), and RSA (ICC = 0.99; *SEM* = 0.01; $n = 16$).

Analysis With Repeated Measures

Repeated-measure ANOVA results revealed significant effects for condition between CC, SS, and DS (Table 2) with

Table 3. Mean difference (%) between different stretching protocols on each of the dependent variables.*

		Condition	Mean change (%)	95% CI for mean lower − upper	p	ES
5 JT (m)		CC vs. SS	−0.8	−0.02 to 0.22	0.10	0.19
		CC vs. DS	1.6	−0.28 to −0.11	0.00	0.37
		SS vs. DS	2.5	−0.49 to −0.10	0.01	0.51
Sprint (s)	10 m	CC vs. SS	2.8	−0.07 to −0.03	0.00	0.39
		CC vs. DS	−2.1	0.02 to 0.05	0.00	0.28
		SS vs. DS	−4.7	0.06 to 0.11	0.00	0.59
	20 m	CC vs. SS	1.7	−0.08 to −0.03	0.00	0.39
		CC vs. DS	−1.0	0.01 to 0.05	0.00	0.25
		SS vs. DS	−2.6	0.05 to 0.13	0.00	0.61
	30 m	CC vs. SS	1.0	−0.06 to 0.03	0.00	0.20
		CC vs. DS	−1.1	0.03 to 0.07	0.00	0.21
		SS vs. DS	−2.1	0.06 to 0.13	0.00	0.40
RSA (s)	Total time	CC vs. SS	−0.2	−0.01 to 0.15	0.09	0.09
		CC vs. DS	0.2	−0.34 to 0.14	0.39	0.12
		SS vs. DS	0.4	−0.43 to 0.08	0.17	0.22
	Mean time	CC vs. SS	−0.2	−0.00 to 0.03	0.12	0.09
		CC vs. DS	0.2	−0.06 to 0.02	0.39	0.12
		SS vs. DS	0.4	−0.07 to 0.01	0.17	0.22
	Best time	CC vs. SS	0.1	−0.03 to 0.01	0.52	0.04
		CC vs. DS	−0.2	−0.01 to 0.03	0.21	0.09
		SS vs. DS	−0.3	0.00 to 0.04	0.02	0.14
	% Dec	CC vs. SS	−7.0	0.02 to 0.48	0.04	0.18
		CC vs. DS	9.8	−1.03 to 0.23	0.19	0.29
		SS vs. DS	19.9	−1.28 to −0.03	0.04	0.45

*ES = effect size; 5JT = 5 jump test; RSA = repeated sprint ability; CI = confidence interval; CC = control condition; SS = static stretching; DS = dynamic stretching.

5JT ($F = 9.99$, $p < 0.000$, ES = 0.40), 10 m ($F = 46.52$, $p < 0.000$, ES = 0.76), 20 m ($F = 18.44$, $p < 0.000$, ES = 0.55), and 30-m sprint time ($F = 34.25$, $p < 0.000$, ES = 0.70). Pairwise comparison showed that a significantly better performance ($p < 0.05$) was observed after DS as compared with that after CC and SS with 5JT (1.6 and 2.5%), sprint times for 10 m (−2.1 and −4.7%), 20 m (−1.0 and −2.6%), and 30 m (−1.1 and −2.1%, respectively). In contrast, significantly impaired performances ($p < 0.05$) were observed after SS as compared with that after CC with sprint times for 10 m (2.8%), 20 m (1.7%), and 30 m (1.0%) (Table 3).

In the RSA, no significant difference was observed between different stretching protocols in total time ($F = 1.55$, $p > 0.05$, ES = 0.09), average time ($F = 1.53$, $p > 0.05$, ES = 0.09), and fastest time ($F = 2.30$, $p > 0.05$, ES = 0.13), except for %Dec ($F = 3.54$, $p < 0.04$, ES = 0.19). However, the post hoc test did not identify any significant pairwise comparison for the %Dec.

Discussion

This is the first study to investigate the effects of SS and DS on performance (sprint, horizontal jump, and RSA) 24 hours poststretching. The results of this study showed positive effects of DS on sprint (10, 20, and 30 m) and 5JT performed the next day. However, SS produced negative effects on these performances compared with that of DS and CC. No significant effect was observed on the RSA, with either stretching condition.

The effects of DS performed 24 hours before explosive performances were similar to those reported by many previous investigations studying the immediate effects of stretching on explosive performances. Both Fletcher and Jones (10) and Gelen (12) indicated that the DS improved sprint performance during warm-up. The positive effects of DS on explosive performances (19), power (21,38), and jump (16–18,25) performance have also been reported. Also, Rosenbaum and Hennig (30) found that the group performing DS protocol was the fastest and had greater tendon stiffness. Behm and Chaouachi (2) in their review calculated an average performance enhancement of 7.3% shortly after DS. Other than the 20-m sprint enhancements, which increased 12 and 24% with DS compared with control and SS, respectively, the other performance enhancements in this study were modest ranging from 1 to 5%. It must be kept in perspective that the Behm and Chaouachi (2) calculation illustrated increases occurring relatively shortly after the intervention whereas the present study still demonstrates significantly greater performances 24 hours later.

Another unique aspect of this study is the demonstration of the negative effect of SS up to 24 hours poststretching. Rosenbaum and Hennig (30) recommended avoiding SS before sprint and strength activities because of its induced effect of decreasing the muscle's elastic energy. Several other studies concluded that performing SS before sprint performances contributed to increased running time (10,23). According to Nelson et al. (23), the decrease in sprint performance was the result of the increased compliance and reduction of muscle tendon unit's stiffness. Fowles et al. (11) have shown that intense and prolonged SS of ankle plantar flexors (13 stretches of 135 seconds each over 33 minutes) reduced the MVC for 1 hour after stretching. Also Power et al. (26) explored the effects of SS of quadriceps and plantar flexors up to 120 minutes, and they demonstrated significant overall 9.5 and 5.4% decrements in the force of the quadriceps for MVC and interpolated twitch technique, respectively. This is the first study to demonstrate persistent SS-induced impairments 24 hours after stretching.

Regarding the RSA test, the results of this study showed no significant difference in the performance after the 3 stretching protocols. The absence of stretching effects performed 24 hours before the RSA test concurred with the study of Wong et al. (37). These authors showed that SS protocol (30, 60, and 90 seconds) performed for 3 consecutive days before repeated sprint had no effect on RSA (9 × 30 m with a 25-second recovery between each sprint). The absence of any effect may also be attributed to a lack of a sufficient stimulus (short stretching ≤90 seconds) (19). Wong et al. (37) have also demonstrated the lack of significant difference in the RSA performance with 30–90 seconds of SS in combination with 90 seconds of DS. However, Beckett et al. (1) have shown that SS reduced the repeated sprint times when the SS was performed during the recovery period between sprints. In this study, the absence of a significant difference between stretching protocols on RSA performance may be the result of this test being performed after the sprint and the 5JT.

Potential mechanisms underpinning these changes in performance are speculative as direct measurements of the physiological mechanisms were not performed. Short-term stretching-induced impairment mechanisms have included both mechanical and neurological responses but have not been fully elucidated (2). In this study, SS might have compromised the effect of a stretch-shortening cycle by decreasing active musculotendinous stiffness, thereby reducing the amount of elastic energy that can be stored and reused (2). The stretch-induced slack in the musculotendinous unit (MTU) can increase electromechanical delay affecting transmission of forces, preventing maximal storage and reuse of elastic energy during the stretch-shortening cycle (23). The SS might also increase tendon compliance, thereby reducing force production (26). The present results suggest that these mechanical alterations may persist for 24 hours. It has also been hypothesized that altered MTU properties through SS inhibit neural potentiation, through changes in reflex activity. However, these neural responses would not be expected to play a substantive role 24 hours after stretching. Conversely, the persistent DS improvements might be attributed to enhanced MTU stiffness, and increased coordination of dynamic movement (2). Mann and Jones (20) in another review suggested that the key attributes of DS include improved kinesthetic sense, leading to improved proprioception and preactivation. From their training study results, Wilson et al. (35) stated that DS might be an effective way to increase the reused elastic energy during exercise involving a stretch-shortening cycle. Unfortunately, this study was not designed to investigate possible mechanisms, but the persistence of these effects for 24 hours warrants further research.

In conclusion, according to the results of this study, the introduction of DS protocol 24 hours before short sprint and horizontal jumps was advantageous; however, SS exercise should be avoided 24 hours before explosive performances despite the absence of effects on RSA regardless of the types of stretching performed.

Practical Applications

Sprint performances (10, 20, and 30 m) and horizontal jumps 24 hours after the DS were significantly better than those after the no-stretch CC and SS. Results of this study demonstrated the negative effect of SS up to 24-hour poststretching. Despite the absence of effects on RSA regardless of the types of stretching performed in the previous 24 hours, it is recommended to perform DS on the day before explosive performances rather than SS because of the positive effects of DS on sprint and jump performance up to 24 hours poststretching.

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